DOCUMENT RESUME

ED 415 657 EF 005 009

TITLE	Carpet and Indoor Air Quality in Schools. Technical Bulletin.
INSTITUTION	Maryland State Dept. of Education, Baltimore.
SPONS AGENCY	American Lung Association of Maryland, Inc.
PUB DATE	1993-10-00
NOTE	9p.
AVAILABLE FROM	Maryland State Dept. of Education, School Facilities Branch, 200 W. Baltimore St., Baltimore, MD 21201 (free to Maryland public schools; $8 for others).
PUB TYPE	Guides - Non-Classroom (055) -- Reports - Research (143)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Carpeting; Elementary Secondary Education; Floor Layers; *Hazardous Materials; Health Conditions; Inspection; Public Schools; Quality Control; *School Buildings; *School Maintenance; *School Safety
IDENTIFIERS	Facility Management; *Indoor Air Quality; Volatile Organic Compounds

ABSTRACT

Ways in which carpeting can affect a school's indoor air quality (IAQ) are discussed. Carpeting is defined as a system of components that includes pads, adhesives, floor preparation compounds, and seam sealers. For the last several years, these products have been increasingly scrutinized as to how they affect IAQ. Carpeting gives off volatile chemical vapors and it is recommended that schools test for volatile organic compounds (VOC) and work to lower these levels in the air. Other factors that school officials should consider regarding IAQ include microbial contamination, particularly through fungi growth, and water intrusion. Some recommended control methods involve using VOC emission data, using antimicrobial treatments, airing new products, minimizing the use of adhesives and sealers, "baking out" new carpet by raising the indoor temperature and then ventilating to accelerate the emission and removal of VOCs, cleaning new carpets with a high-efficiency particulate air filtration vacuum, and providing routine maintenance for the carpet, such as a vacuuming schedule, prompt stain removal, and shampooing or hot-water extraction. The strengths and weaknesses of having carpeting in a school are discussed. (RJM)

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ED 415 657

CARPET AND INDOOR AIR QUALITY IN SCHOOLS

October 1993
Maryland State Dept. of Education
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EF 005 009

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Introduction

Public school systems have used carpet in school buildings for years. It has several advantages as a floor covering system. Carpet can act as an excellent material for controlling both airborne and impact noises. It can provide comfort to students and teachers with a yielding surface under foot and a thermally acceptable surface for work and play. Carpet may reduce the incidence of slips and falls as compared to hard surface floors and reduce injury if a fall does occur. Carpet is often considered to add a desirable appearance to a room.

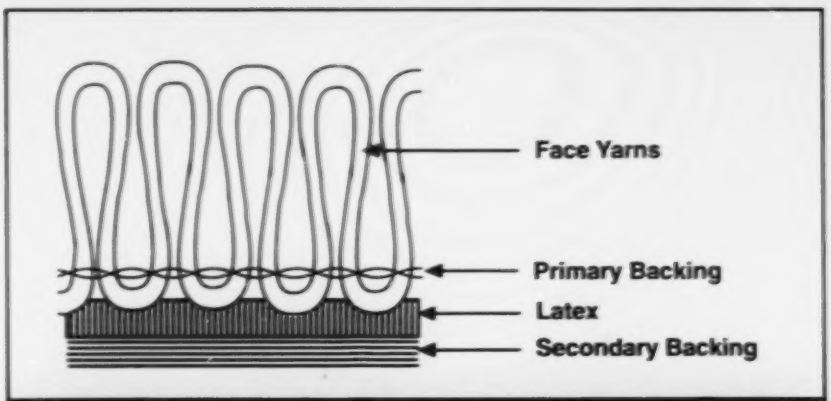

FIGURE 1
SECONDARY - BACKED TUFTED NYLON CARPET

"Carpeting" is a system of components. This system usually includes not only the carpet, but also the pad (cushion), adhesive, floor preparation compounds and/or underlayment, and seam sealers. Secondary backed tufted nylon carpet is used most frequently in schools (see figure 1). The tufted construction process involves the attachment of the face yarns to the primary backing of the carpet. The underside of the primary backing is coated (usually with latex rubber) to lock the yarn to the backing. A secondary backing is placed on the underside of the primary backing for greater stability. A pad or cushion is sometimes placed under the carpet to provide resiliency, support, and noise absorption. The carpet is typically "glued-down" to a concrete surface that has been prepared with a sealer. Unitary backed tufted carpet is another carpet type used in schools. This carpet employs a special formulation latex coating applied to the primary backing and does not use a secondary backing.

Over the last several years, carpet products have received much scrutiny in relation to indoor air quality. Topics have focused on emissions of volatile organic compounds (VOCs), carpet as a potential reservoir of contaminants, and the importance of careful selection, installation, and maintenance of carpet systems. As the attention on carpet has intensified, information coming to the consumer is often incomplete, conflicting, and confusing. The intent of this bulletin is concisely to present and clarify information on the issues, identify areas where adequate information does not exist, and discuss carpet-related sources of potential air contaminants and means of control.

Volatile Organic Compounds

Volatile chemicals produce vapors readily at room temperature and normal atmospheric pressure. There are many sources of VOCs in buildings. Most products used in the construction or renovation of buildings emit volatile organic compounds into the air. These emissions typically decrease over time. During the "life" of a building, VOC emissions occur through the use of maintenance, operations, and instructional materials and equipment.

Very limited research has been conducted linking specific VOCs at known common indoor air concentrations to effects on human comfort and health. We know that usually hundreds of VOCs are typically found in the non-industrial indoor environment. Concentrations are ordinarily 100 to 1000 times lower than occupational threshold values. Studies have shown that the most frequent effects of low level VOC exposures are stimulation of the senses, inflammation of exposed tissues, and stress-like reactions such as headache or fatigue. There are people who believe that their health problems are related to exposure to carpet emissions or began following carpet installation, however, little definitive information is known about the effects of VOCs from carpet systems on human comfort and health.

The various permissible exposure limits for occupational exposures to VOCs illustrate that the health and comfort effects of different VOCs vary significantly. Some VOCs can produce responses in individuals at very low concentrations. Additionally, combinations of VOCs may produce additive or synergistic effects in certain individuals.

Anderson Laboratories, Inc. in Dedham, Massachusetts has conducted research exposing mice to air drawn from a chamber in which a carpet sample is heated. Anderson reported that upon repeated exposures some mice died, and many experienced serious neurological effects. This research is mentioned because there has been significant publicity and controversy surrounding the interpretation of these tests. The Anderson tests are surrounded by controversy about methodological issues. At this time, building owners and managers are advised not to draw any conclusions from the reported test results.

To begin controlling VOC sources one must understand what sources are potentially the largest contributors. The emissions of VOCs from carpet have been only one area of concern. VOC emissions from the carpet alone are typically small when compared to other components of the carpet system and many other building materials. Styrene-butadiene rubber (SBR) latex used in the backings of a majority of new carpets emits a variety of VOCs including 4-phenylcyclohexene (4-PC). The odor of 4-PC is easily detectable at extremely low concentrations; it is the odor that most people associate with recently installed carpet. Other VOCs often emitted from carpet are styrene, 4-vinylcyclohexene, undecane, decane, toluene, xylene, and other aromatic hydrocarbons.

Solvent-based carpet adhesives in glued-down installations represent the most significant source of VOCs. Carpet adhesive traditionally is a mixture of synthetic rubber, resins, and fillers. The resin remains as a solid at room temperature. Solvents are used in dissolving the resins into a liquid. Ninety to ninety-five percent of the total VOCs in carpet adhesives are introduced during this process. Because of the indoor air quality issue, adhesive manufacturers have recently developed low-solvent and solvent-free adhesives, resulting in low VOC emitting adhesives (see figure 2).

Seam sealers are another large source of VOCs but the least significant by volume among adhesives. Manufacturers of seaming compounds have developed low-emitting products.

Carpet pads may also be a source of VOC emissions. VOC emissions from carpet pads are currently being studied with information anticipated in the near future.

VOC Testing

The Carpet and Rug Institute (CRI), a trade association representing about 95% of the industry, has established a VOC testing program for carpets. This program is the result of a U.S. EPA Carpet Policy Dialogue with other government agencies, and representatives from the carpet industry, interest groups, and scientific organizations. The Carpet Policy Dialogue was begun in response to a petition from The National Federation of Federal Employees. That petition sought to reduce VOC emissions from new carpet products because of their members' concerns after carpet installation and related reports of adverse health effects. The CRI test measures total VOCs (TVOCs), styrene, 4-PC and formaldehyde. Once each year, a sample of each carpet type is cut directly from the manufacturing line, packaged and delivered to a lab and tested within 36 hours. CRI's testing criteria include total VOCs (less than 0.6 mg/m2·hr), styrene (less than 0.4 mg/m2·hr), 4-PC (less than 0.1 mg/m2·hr) and formaldehyde (less than 0.05 mg/m2·hr). If the carpet passes the test, it is tagged with a CRI indoor air quality label before distribution to retail showrooms.

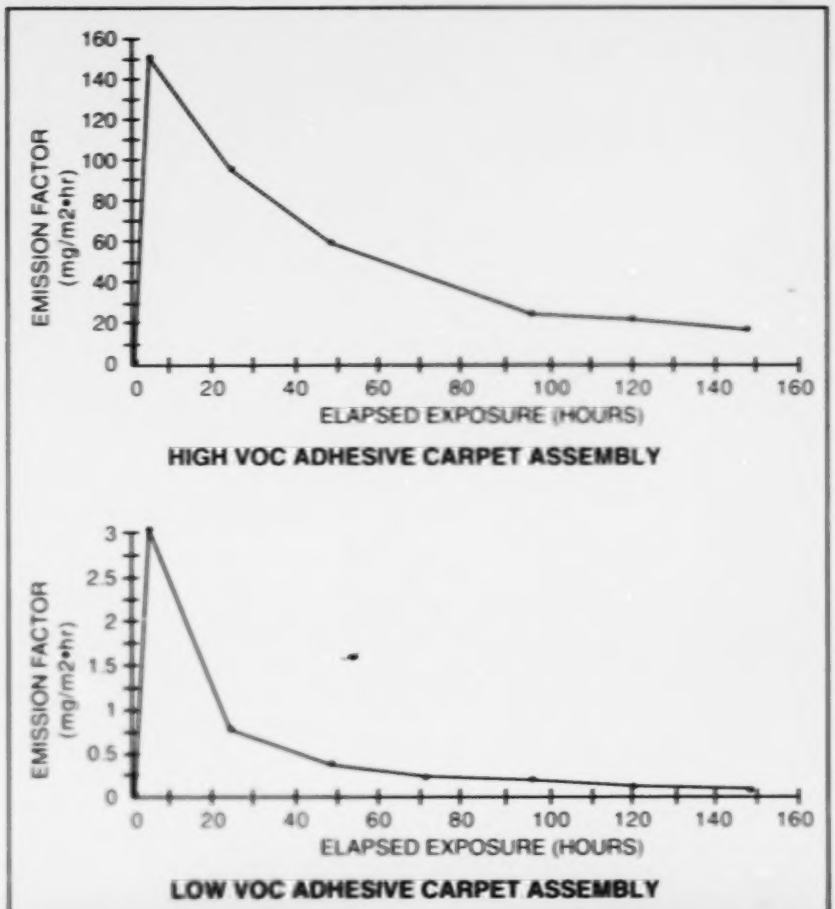

FIGURE 2
TVOC EMISSION PROFILE

There is general agreement that lowering TVOC emissions is in keeping with the goals of improving indoor air quality. However, caution surrounds interpretation of the results from TVOC testing because it does not provide information on the comfort and health effects of specific VOC emissions. The test does not identify individual compounds (other than styrene, 4-PC and formaldehyde) and their corresponding concentrations. Therefore, the CRI indoor air quality testing program label should not be misunderstood to assure a safe product.

Other questions surface about the meaning of test results from the CRI program. For example, does the chemical make-up of individual carpets in a carpet testing category vary significantly and has quality control in the carpet manufacturing industry reached an acceptance level such that one test of a carpet type each year adequately characterizes all batches of carpet throughout the year? An article in Indoor Air Bulletin (vol.2. no.6, page 4) discusses a report on VOC emissions from carpets conducted for the Consumer Product Safety Commission. The article concludes that potentially significant variations do exist in the dominant compounds emitted from carpets that may be similar in construction.

Other Factors

Microbiological Contamination

Microorganisms are found in all environments and can result in odors, stains, deterioration of building materials, and human infections and allergies. All buildings will have background levels of microorganisms. Usually problems arise when microorganisms reach atypical levels. The most frequently discussed microorganisms, in relation to carpet, are fungi and dust mites. The Institute of Medicine recently identified carpet as a potential significant source and reservoir of indoor allergens that should be given consideration as a serious problem. One study (Gravense, S., et al, Allergy 1986, 41, 520-525) found that rooms (in schools and offices) with carpets have significantly higher concentrations of dust than bare floors and that microfungal counts were significantly greater in dust from carpets than in dust from bare floors. However, researchers in Denmark have found that frequent and effective vacuum cleaning can maintain dust levels as low in carpets as on bare floors.

Fungi can be a primary irritant and also produces mycotoxins that can cause illness in certain people. Fungi can cause allergic reactions for a significant portion of the human population. While most adverse health effects are seen in allergic individuals, the same microbes may sensitize susceptible (but previously non-allergic) individuals.

There is general agreement that dust mite concentration will be higher on carpeted floors than on hard surface flooring. The number of dust mites is highly dependent on the presence of human skin scales (their main food) and humidity. The dust mites themselves are not thought to be harmful. It is the fecal product from dust mites that causes an allergic reaction in some people. Approximately one third of the general public, including children, have skin test evidence of allergy to dust mites. Dust mite exposure is important in asthma, a widespread disease that is a significant cause of student absenteeism.

Water Intrusion

Water intrusion will often lead to biological contamination. Carpet may become saturated with water from unanticipated leak sources such as pipes, roofs, or through on-grade concrete slabs. Moisture can also be introduced into carpet from improper wet cleaning techniques or high relative humidity in the building.

If carpet does become saturated and water is not quickly removed (<24 hrs.) from the carpet system, experience suggests that in most situations the carpet will have to be discarded. Disinfection is rarely effective and disinfectants can become a source of VOCs that may produce unwanted health effects in some individuals.

Control Methods

Product Selection

VOC Emission Data

Manufacturers of building materials should be asked to submit information about emissions from their products. Realistically, information on emisssions is not always available from manufacturers of the hundreds to thousands of products used in school construction projects. However, this information is becoming increasingly available as is true in the carpet flooring products industries. The State of Washington has adopted emission rate standards that manufacturers must not exceed for state construction projects. Insistence by building owners on receiving this information will advance the development of product-by-product testing and standardized testing methods for a wide array of products.

School designers should ask manufacturers to submit the following information for each product making up the

Carpet flooring system products are not the only building materials that should receive attention about VOC emissions. School designers and specifiers should begin by choosing to focus their inquiry on a limited number of products having the greatest impact on the indoor school environment. The focus should be on products having the largest surface areas or the highest total weight per volume of space in a school building. Wall, ceiling, and floor surfaces are apparent choices indicating the importance of paint, ceiling tile, carpet flooring systems, and vinyl tile flooring. Furniture and built-in cabinetry are products of importance as well.

carpet system:

- The material contents of the product
- Identification and quantified amounts of substances that are listed on either: (a) the International Agency for Research on Cancer List of Chemical Carcinogens; (b) the Carcinogen List of the National Toxicology Program; or (c) the Reproductive Toxin List of the Catalog of Teratogenic Agents
- Emission factors for VOCs contained in the product (mg/m2-hr)
- Product TVOC emission factor (e.g., 1, 7, 30 days after manufacture for solid products such as carpet and 1, 4, 24, 48 hours for wet products such as adhesives) (mg/m2-hr)
- The emissions test protocol used
- The organization evaluating the product

While emission data can be used to evaluate products, a small difference between products is not meaningful or a basis for selection. When selecting carpet system products the designer must consider emission data along with similar information on the products necessary for proper maintenance of the flooring system. The frequency that the carpet flooring system has to be replaced over several decades (with corresponding emissions) should be factored into product selection. A more durable, long-lasting flooring system will lessen the frequency of emissions from replacement materials.

The CRI testing program can be used as a first hurdle for carpet product selection. Carpet not meeting the CRI test program should not be considered for use in schools. Non-CRI members should be required to meet the same standard.

Adhesives used in the carpet system have been the greatest source of VOC emissions, and therefore, must be a primary focus in the selection of materials. There are six carpet installation adhesive product classifications: carpet, multipurpose, pressure sensitive, vinyl backed, pad cement, and seam sealer. Carpet and multipurpose adhesives represent about 75% of the market and are typically used for "glue-down" in schools.

The adhesive industry is now producing low VOC emitting carpet and multipurpose adhesives. The low TVOC adhesive products are sometimes not received well by the installer. Their complaint is the longer time for the adhesive to set-up to receive the carpet although the ultimate adhesion is acceptable. Installers may be reluctant to change existing work habits requiring them to spread a larger area before going back to lay the carpet. Building owners should stress that low-emitting adhesives are the product of choice.

Antimicrobial Treatment

Carpet can be treated with an antimicrobial agent in the manufacturing process. The agent is added to the fiber or to the backing. Carpet with an antimicrobial treatment represents a very small percentage of the carpet market and is usually specified for specialized situations such as hospitals and nursing care facilities.

Antimicrobial treatment introduced in the manufacturing process is not recommended for Maryland schools. Antimicrobial treatments are pesticides. As such, antimicrobial treatment should be a solution of last resort rather than a preventive technique specified for all carpet installations. This approach is particularly important in schools, because the student population is regarded as a higher risk group than the general adult population. The cost for mill-applied antimicrobial treatment (about $.35 - $1.00 per square yard) would better be spent on the maintenance of carpet.

Minimizing microbiological contamination in carpet should be a preventive program after installation with the primary focus being a strict regimen of maintenance (see section on maintenance, page 6). Antimicrobial treatment may be an option worthy of evaluation, but only in a limited number of situations of severe contamination.

Installation

Airing New Products

Unwrapping and unrolling carpet in a well ventilated location is desirable for lowering VOC emissions prior to installation. Airing prior to installation should be for a minimum of 24 hours but ideally not less than 48 hours. Airing should occur in a location other than the school, such as a ventilated warehouse. However, leasing space outside the building may involve unacceptable costs.

Airing out the space during and after carpet installation is essential and is recommended by the Carpet and Rug Institute, the U.S. Environmental Protection Agency, and the U.S. Consumer Product Safety Commission. The typical recommendation is to continuously operate the building ventilation system at normal temperature and maximum outdoor air during installation and for 72 hours after installation is completed. The CRI Standard for Installation of Commercial Textile Floorcovering Materials (CRI 104) addresses the topic of airing and other installation procedures.

Recirculation of air from the area of installation into the HVAC system should be prevented. Ductwork and plenums may have materials (e.g., duct liners, spray-on fireproofing, ceiling tiles) that are potentially capable of adsorption and re-release of VOCs. Temporary exhaust patterns can be created using fans, open doorways, stairwells, and windows.

The State of Washington employs a 90-day flush-out program. After carpet installation the HVAC system in the unoccupied building is operated at maximum outside air, 24 hours a day for 30 days. Washington's mild climate permits the use of maximum

outdoor air ventilation with very little energy penalty. After 30 days, the furniture is installed and the building HVAC system is operated for an additional 60 days at maximum outside air. While time frames of this length may not be available between carpet installation and occupancy for most school construction projects, a minimum of 72 hours airing is recommended after carpet installation.

In renovations, carpet installation should occur only when the school building is not in use. One exception would be for small installations in which the space can be exhausted directly to the outdoors causing the room to be under negative pressure. Ventilation should continue for a minimum of 72 hours after installation. With a central HVAC system the ventilation supply should be on and the return grille(s) sealed.

Application of Materials

Specifications should state clearly that the least amount necessary of wet materials such as adhesives, seam sealers, and sealants be used by the carpet installer. These specifications should be provided by the manufacturer. Wet materials should be allowed to dry to the maximum extent and still meet the required performance. Specifications should state that the contract can be awarded only to a floorcovering company that has a written hazard communication program.

Bake-Out

Bake-out involves raising the indoor temperature to higher than usual and ventilating a building to accelerate the emission and removal of VOCs. This can be accomplished using the HVAC system sometimes supplemented with lighting or portable space heaters. Bake-out for carpets on concrete slabs includes significantly raising the temperature of the slab. This can easily take several days of constant heating.

A bake-out can be expensive since it requires careful planning and execution by knowledgeable individuals. A bake-out may damage equipment, furniture, building materials and could have implications for warranties.

Bake-out is not recommended primarily because the effectiveness of this technique has not been conclusively proven. More research is needed, especially in light of the associated potential problems.

Cleaning

After the carpet flooring system has been installed during a major construction project and before occupancy, the carpet should be cleaned by the carpet installer with a high efficiency particulate air (HEPA) filtration vacuum. This procedure will remove loose fibers and particles generated by the final stages of construction. In renovations, existing carpet should be cleaned with a HEPA vacuum prior to removal. The subfloor should also be vacuumed. These procedures will reduce the release of particles in the carpet such as fungi.

Maintenance

The aspects of carpet maintenance most important to managing indoor air quality are vacuuming, spot treatment, periodic and emergency cleaning, and preventive maintenance.

The majority of carpet in schools will require daily vacuuming because schools are uniquely trafficked buildings. Unlike office buildings, schools contain primarily high traffic areas such as hallways and classrooms. In a 1990 study of custodial management practices and costs in office buildings by the Building Owners and Managers Association, Intl., the majority of respondents claimed that only 10% or less of the building could be considered heavy public use areas. Over one-half of the respondents indicated that at least 78% of the building involved low-traffic areas. In contrast, school buildings, particularly elementary schools, have a majority of floor area classified as heavy traffic areas.

With the decision to use carpet in a school comes a corresponding commitment to implement a preventive and scheduled maintenance program. If this commitment cannot be executed due to budget constraints, inadequately trained staff, or other reasons, carpet should not be used. Without proper maintenance, carpet will have a shortened life span and will become a contaminant source for the indoor air.

A vacuuming schedule should be developed for all carpet areas based on traffic rate and the potential for soiling due to instructional or other activities (see figure 3). Daily vacuuming will be required in the majority of carpeted areas when a school is in full use. Regular vacuuming minimizes the particles that will work down into the pile. Effective vacuuming is achieved when agitation of the carpet pile is combined with suction to remove soil. Vacuum cleaners with a revolving cylinder of brushes and a strong suction provide the best cleaning for glue-down carpet applications. However, information is not available on the effectiveness of vacuuming to remove specific types of particles. Some vacuum cleaners may, in fact, disperse fine particles into the air. Two motor vacuum cleaners with sealed compartments for the collection bag and at least 5 micron filtration are recommended. Vacuuming procedures should specify a slow forward and backward motion over the same spot rather than several rapid strokes. If an indoor air quality evaluation suggests more effective vacuuming is required, a HEPA filtration vacuum should be used.

- **HIGH TRAFFIC AREAS**
  (e.g. most instructional areas, administration reception area, media center circulation area)
  Daily (or more frequently as indicated by inspection)

- **LIGHT OR MEDIUM TRAFFIC AREAS**
  (e.g. conference rooms, office space)
  Once or twice weekly (or more frequently as indicated by inspection)

FIGURE 3
VACUUMING SCHEDULE
NOTE: BECAUSE EVERY FLOOR AREA DIFFERS IN TRAFFIC COUNTS AND SOILING RATES, THIS FIGURE IS MEANT TO BE A GUIDE ONLY.

Most stains can be removed if they receive prompt treatment. The greater the time lag the more difficult it is to remove a stain. If not left to dry, nearly all common stains can be removed with mild soap and water. Sugar-based stains (sweetened coffee, tea or sodas) should be attended to immediately and rinsed several times. If left to dry before cleaning, stains may become permanent. A spot removal kit, either purchased as a kit or compiled, should be available in every building with carpeting. Some spot cleaning products are solvent-based and may introduce VOCs. Citrus-based cleaning products are available that may be less offensive to building occupants.

The Carpet and Rug Institute discusses five carpet cleaning techniques in the CRI Commercial Carpet Maintenance Manual but does not recommend techniques for specific carpet types and applications. CRI points to the lack of research on cleaning techniques as the reason for not making recommendations. Most carpet maintenance experts, however, judge hot water extraction and shampooing to be the most effective cleaning techniques. These wet cleaning methods are also effective in controlling the dust mite population.

While periodic cleaning practices in Maryland vary from school system to school system, shampooing or hot water extraction are the predominant choice, sometimes in combination. If hot water extraction is the single method of choice, the minimum cleaning frequency should be once each year for light traffic areas, twice each year for medium traffic areas, and three times a year for heavy traffic areas. If hot water extraction is used in combination with several shampooings each year, extraction can be reduced to once each year. The advantage of shampooing and hot water extraction in combination is the application of detergency, agitation, and extraction to the cleaning process. This combination is very effective.

Shampooing and hot water extraction cleaning must be done by trained staff and with properly maintained equipment. Over-wetting must be avoided and the carpet should be dried within 24 hours. The drying process may require supplementary ventilation.

Preventive "maintenance" includes general awareness of building occupants to avoid spillage of liquids on carpet. Effort should be made to educate staff and students in this regard. One important preventive technique is to specify walk-off mats or foot grilles at the entrances and vestibules of the building. In this manner, soil and snow will be collected and trapped before it reaches the interior of the school.

Conclusions and Recommendations

- As with any flooring system, carpet has strengths and weaknesses. Strengths include: noise control, comfort under foot, and the potential for reduced falls and injury as the result of a fall. Weaknesses include: the emission of VOCs during and after installation, the requirement of an intensive maintenance program to prevent elevated contaminants from the carpet system, and a greater potential as a source for dust mites and fungi than hard, dense surface flooring systems such as vinyl tile or terrazzo.

- Because of a high density of occupants and varied programmatic uses, carpet systems in schools require an intensive maintenance program as compared to carpet in office buildings. The vast majority of carpet in schools requires daily vacuuming and wet cleaning (shampooing and/or hot water extraction) several times each year.

- Carpet flooring systems should be selected only if the required maintenance program will be implemented.

- There is no scientific information specifically linking carpet system VOC emissions to health effects in humans. However, studies do show a link between general low level VOC exposure and detrimental health effects in certain individuals.

- The Carpet and Rug Institute's VOC testing program generalizes about carpet emissions, addresses one component of a multi-faceted carpet floor covering system, and does not guarantee a safe product. While understanding the limitations of the Carpet and Rug Institute VOC testing program, only carpet products meeting the CRI test program criteria should be specified. Carpet manufacturers not represented by CRI should be required to meet the same standard.

Continued on page 8

- The VOC emissions from carpet systems (particularly from traditional solvent-based adhesives) are significant but are not unlike those of vinyl tile flooring systems and can be largely controlled by careful selection of carpet and adhesive products, and installation/post-installation procedures.

- Low VOC emitting carpet or multi-purpose adhesives should be specified.

- Antimicrobial treatments introduced in the manufacturing process are not recommended.

- Carpet should be aired before, during, and after installation. Before-installation airing should be a minimum of 24 hours and ideally 48 hours. After-installation airing should be a minimum of 72 hours.

- Building bake-out techniques are not recommended.

- Carpet should not be used for extremely heavily trafficked areas in schools such as entrances and corridors. The required maintenance is too time consuming and costly.

- Carpet should not be placed in proximity to water or flood sources such as drinking fountains, classroom sinks, cafeterias, and teacher dining rooms.

- Carpet should not be used in areas of an existing building where moisture problems are known, such as leakage through an on-grade concrete floor. ■

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Figure 2.
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This Bulletin was developed and published, in part, with funds from the American Lung Association of Maryland.

Participation on The Bulletin Review Committee does not imply agreement with the entire content of this bulletin.